MAKING JAM COMMERCIALLY

PRINCIPLES – METHODS – EQUIPMENT – FORMULAS

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CONTENTS

MAKING JAM COMMERCIALLY[1]

Principles • Methods • Equipment • Formulas

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This publication was prepared for the small manufacturer or processor thinking of entering the jam-making business. It gives information gained from laboratory studies, practical experience and other sources.

The principles involved in the manufacture of high quality jam are briefly discussed. For a more thorough treatment of theoretical aspects, consult the excellent book by Rauch (5) and the *Preservers Handbook* (9). Larsen (4) gives further information on the use of pectin in jams.

Only the manufacture of pure fruit jams is discussed in this publication. However, the same procedures apply to other grades.

LEGISLATION

Regulations governing the manufacture of jam in Canada are contained in the *Meat and Canned Foods Act* (2) and the *Food and Drugs Act and Regulations* (3). A processor considering making jam commercially should be thoroughly conversant with both these acts.

Canadian Standards for Jam

Canadian standards for jam call for definite, minimum percentages of fruit and total soluble solids in the finished product. The percentage of fruit varies with the grade and kind of jam. The minimum percentage of fruit for all Canadian jams except strawberry is 45; for strawberry it is 52. That is, every 100 pounds of finished jam contains 45 or, if it is strawberry, 52 pounds of fruit.

The minimum percentage of soluble solids is 66. As practically all of the soluble solids are sugar solids, this figure is a good indication of a jam's total sugar content. Aside from the legal aspects, jam containing less than 65 percent sugar is subject to spoilage from yeasts and molds.

Containers and Labels

Jam for the retail trade in Canada is packed in both glass and metal containers. The sizes listed in the *Meat and Canned Foods Act* (2) are $2\frac{1}{2}$, 6, 9, 12, 24

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and 48 **fluid ounces.** By weight, these are about $3\frac{1}{3}$, 8 and 12 ounces and 1, 2 and 4 pounds, respectively. All labels must be approved by the Minister of Agriculture. Special dispensation may be granted to pack jam in containers smaller than $2\frac{1}{2}$ fluid ounces and larger than 48 fluid ounces.

TWO METHODS OF MAKING JAM

Jam is manufactured by either the open-kettle or the vacuum-kettle process. In general, because of lower processing temperatures, jams made by the vacuum process have better color and flavor than those made in an open kettle.

Open-kettle Process

In the open-kettle process the jam is boiled under atmospheric conditions. During the boiling process the batch temperature may exceed 225° F. Prolonged heating at high temperatures, however, should be avoided as it causes excessive caramelization of sugar, low flavor and poor color. This process can be used to advantage in small-scale operations, such as specialty packs. (For more details on advantages and disadvantages of this method see "Vacuum process".)

Vacuum Process

In the vacuum process the batch temperature should not exceed 160° F. except for a brief period before filling, when it may be raised to 180–190° F. to ensure a good vacuum and sterile fill.

Advantages of the Vacuum Process

1. Short, low-temperature boil preserves color, flavor and wholeness of fruit pieces.
2. There is less inversion of sugar than when jam is boiled at atmospheric pressure and temperature.
3. Overheating is avoided, since size of batch is not influenced by temperature and time it takes for steam bubbles to pass through the batch.
4. Larger batches can be processed than with the open-kettle method.
5. Sugar penetration to the center of the fruit is better and easier.
6. Less manual labor is involved.
7. Ester recovery can be practical.

Disadvantages of the Vacuum Process

1. Initial installation of equipment is very expensive.
2. Expensive automatic control instruments are necessary when processing large batches.
3. A large volume of cooling water is required for condensers.
4. Vacuum equipment is not practical except for large runs or batches.
5. Sulphur dioxide removal from SO_2-preserved pulps is not satisfactory. Vigorous boiling of SO_2 pulp under atmospheric conditions is required to remove sulphur dioxide from the pulp. This defeats the purpose of a vacuum process.

INGREDIENTS

Besides fruit, jam contains sugar or other sweetening agents, pectin, acid and water. The sugar and acid cause the pectin to undergo a physical change, when conditions are right, forming a gel in which the fruit is suspended. The active acidity (pH) must be carfully controlled to obtain a gel formation. In fact, all ingredients must be present in definite proportions if a jam of desired set or consistency is to be obtained.

Fruit

Jams may be prepared from fresh, frozen or canned fruit or SO_2 pulp. Only fully mature fruit of characteristic color, flavor and texture should be used. Fresh and frozen fruit produce the best quality jam and are the only ones dealt with in this publication. In Canada, strawberry and raspberry pulps preserved in SO_2 are not permitted in pure jams.

Carefully sort and wash fresh fruit. Pit apricots, cherries and prunes, either by hand or by machine; peel and pit peaches; and stem strawberries and currants. Simmer firm fresh fruits such as cherries, plums and apricots in a small quantity of water to soften the flesh before adding any sugar. Most berries do not need this treatment.

Sweetening Agents

The main sweetening agents used in jam are cane and beet sugar (sucrose), corn sugar (dextrose), corn syrup (glucose), invert sugar (dextrose and levulose) and honey. They differ in solubility and in their effects on the color and flavor of the jam. A combination of sucrose and invert sugar is usually the best sweetener for the inexperienced jam maker to use.

Technically, invert sugar is a mixture of **equal** parts of dextrose and levulose and is formed when sucrose is broken down by acids or certain enzymes. This process is called **inversion.** Dextrose and levulose are also called simple, or reducing, sugars. The fruit in a jam contains these two sugars in different proportions as well as other simple sugars. When a jam is analyzed all the simple sugars are grouped together and reported as **percent reducing sugar.** Generally, the industry refers to these sugars as "invert".

In jam making, some inversion takes place during the cooking. The rate and amount are controlled by the pH of the jam, the boiling temperature and the length of the boil.

Jam must have a proper balance of sucrose and invert (reducing) sugar, or one or the other may crystallize during storage. Jam with total soluble solids of 68 to 70 percent should analyze 20 to 28 percent reducing sugar. In other words, 30 to 40 percent of the sugar present in the jam should be invert.

Because it is not always possible to obtain the proper sucrose–invert sugar ratio during the boiling process, some preinverted sugar syrup is usually added. This is particularly true in the vacuum process, in which, because of the low boiling temperature, practically no inversion occurs. Even in the open-kettle method, low-acid fruits would have to be boiled so long to get sufficient inversion that it would affect the color and flavor of the jam.

Preparation of Invert Syrup

Invert syrup is made from cane or beet sugar dissolved in water and treated with an acid, such as citric, tartaric, hydrochloric or phosphoric. After inversion, and before cooling, sodium bicarbonate is sometimes added to neutralize most but not all of the acid. However, if the syrup is to be used with low-acid fruits no neutralization is necessary.

The following method gives a light-colored, invert syrup of 70 percent soluble solids that are at least 96 percent invert sugar. Dissolve 100 pounds of cane sugar in 45 pounds of water and add 5 ounces of citric acid. Keep the mixture at 212° F. for 1 hour with agitation. Immediately cool the syrup to about 100° F. and adjust with water to 70 percent soluble solids.

Glucose

Some manufacturers use glucose (corn syrup) for 5 to 15 percent of the sugar in a jam because they feel it improves the quality. Glucose is slightly less sweet than sucrose, has a high viscosity and seems to brighten the jam. It also retards the crystallization of sucrose.

When glucose is substituted for part of the sucrose in a jam, an equal amount of sugar solids must be provided. For example, if the glucose contains 60 percent sugar solids, use $\frac{100}{60} \times 1 = 1.67$ pounds of glucose to replace 1 pound of sucrose.

Pectin

All fruits contain some pectin but the amount and quality vary with the fruit, its ripeness and the conditions under which it was grown. For this reason it is usually necessary to add commercial pectin to obtain jam of uniform consistency.

Pectin can be purchased by grade in either powdered or liquid form. Grade does not refer to quality but indicates the number of pounds of sugar 1 pound of pectin will set into a standard sugar–pectin jelly under specific conditions. For example, 1 pound of 100-grade pectin will set 100 pounds of sugar into a standard jelly of 65 percent soluble solids, if enough acid is present. One grade may be substituted for another if proper adjustment is made; that is, for the same gelling power of 1 pound of 100-grade pectin you would need 2 pounds of 50-grade pectin.

Two types of pectin are used in jam making: **rapid set** and **slow set.** With rapid-set pectin the jam thickens soon after the acid is added. This helps to keep fruit pieces uniformly distributed throughout the jam instead of floating to the top. Normally the containers are filled hot, above 185° F., and cooled without agitation.

For a low-temperature fill, often used with vacuum jam and jam filled aseptically, slow-set pectin is used. It is also needed if containers are to be spin-cooled. Spin-cooling jams made with rapid-set pectin destroys the gel and gives a weak set or runny jam. According to Seymour (7), slow-set pectin will not start to gel for at least 40 minutes at temperatures as low as 165° F. This allows time to fill, cap, wash and label the containers before the jam starts to set.

Pectin may be added to the jam either as a dry powder or in solution. The pectin must be completely dissolved to contribute to gelling. Pectin dissolves best if the sugar solids are less than 20 percent. Therefore, if powdered pectin is being added directly to the jam it must be mixed with part of the sugar and added at the start of the boil, before the bulk of the sugar is added. On the other hand, a pectin solution may be added at any time during the process. This is an advantage because prolonged cooking, especially with acid fruits, usually destroys some of the pectin, lessening its gelling power.

A 10 percent pectin solution is the most practical to use. Prepare it as follows: Mix 10 parts of powdered pectin with 20 parts of sugar in a dry container. Add this mixture slowly to 70 parts of boiling water, with constant agitation. Continue stirring until the pectin is completely dissolved—this takes only a few minutes. As the pectin solution is not stable (it loses some jellying strength on standing), prepare only one day's supply at a time.

Acid

Fruits contain natural acids but many of them do not have enough for a satisfactory set or gel. To make up for this deficiency, and to add tartness and improve the flavor, acids such as citric and tartaric are normally included in

jam formulas. The amount of acid used varies with the fruit and may be added either as a liquid or as a powder.

The pH (active acidity) should be determined with an electric or battery-operated pH meter. In a jam of 68 to 70 percent total soluble solids, keep the pH between 3.2 and 3.4. No gel will form above a pH of about 3.6, while below 3.0 the jam tends to sweat, causing excessive weeping or bleeding later.

To bring out a characteristic fruit flavor, it was often necessary in our studies to use a pH slightly higher or lower than the theoretical ideal. This meant we had to use a little more pectin or possibly accept a lighter set, but the improvement in quality was often worth the change. We had to be careful, however, to keep the pH within the limits necessary for satisfactory gel formation.

PROCESSING

The steps in making jam are outlined in the flow sheet (Figure 1). Whether the operations are manual or automatically controlled depends on the scale of production (see Processing Equipment, page 12). In any case the equipment must achieve the following to give good quality jam: (*a*) a rapid boil so that batches can be finished in 7 to 8 minutes (this requires a steam working pressure on the kettles of 70 to 100 pounds per square inch); (*b*) a rapid cool from the boiling temperature to 160° to 190° F. (this temperature depends on the type of fill); and (*c*) final cooling of the jam in closed containers to 90° F. before casing.

Frozen or SO_2 Fruit — *Fresh Fruit* — *Canned Fruit*

Fresh Fruit → Washing → Stemming, peeling, pitting, etc. → Slicing or cutting (joined here by Frozen or SO_2 Fruit and Canned Fruit) → Adding sugar → Concentrating → Filling → Cooling → Labeling → Casing

Figure 1.—Flow sheet for making jam.

Open-kettle Process

Using Fresh Fruit

1. Place the weighed fruit and water (usually about 20 percent by weight of the fruit) in the kettle. Turn on steam and simmer fruit for 3 to 5 minutes with agitation, to soften fruit pieces.

2. Add the sugar and bring batch to a vigorous boil with agitation. After 5 minutes (assuming total boil time is 7 to 8 minutes) add pectin solution (see page 6).

3. When jam thermometer shows mixture is 3 degrees from finishing point, add acid.

4. When finishing point is reached, shut off steam and check soluble solids on a cooled sample of the jam, using a refractometer (see page 10).

5. Draw off jam, fill containers at 185 to 190° F. and seal immediately.

6. Water-cool cans and air-cool jars to at least 90° F. (Glass jars are available that the manufacturer claims can be hot-filled and immediately subjected to cold-water sprays or immersed in cold water without breakage.)

Using Frozen Fruit

Frozen fruit can be thawed in the kettle. However, it is usually preferable to remove the frozen fruit from cold storage and allow it to thaw overnight at room temperature. In most instances, water can be omitted from the formula unless there is insufficient free liquid from the thawed fruit to dissolve the sugar and prevent scorching.

Drain the juice off the thawed fruit into the kettle, dissolve the sugar in it and bring to a boil with agitation. Add the fruit and reheat mixture to the boil. After approximately 5 minutes add the pectin solution. Finish as outlined in *3*, *4*, *5* and *6*, above.

A quicker method is to place the thawed fruit (including juice) and the sugar in the kettle together, instead of dissolving the sugar in the juice as suggested. In larger plants a predissolving kettle is used and the mixture is pumped to the kettles as needed. Jam made this way, however, has fewer pieces of whole fruit.

Control of Finishing Point

When using the open-kettle process, check the boiling point of the water at least twice a day. The boiling point of a liquid depends on the atmospheric pressure in the area. A decrease in pressure of ½ inch of mercury lowers the boiling point of water 1° F. Variations in atmospheric pressure during the day, or from day to day, may cause the boiling point to vary as much as 2° F. An error of 1° F. in the finishing point of a jam causes an error of almost 2 percent in the soluble solids of the finished product. If a jam is finished to 70 percent soluble solids instead of 68, the manufacturer is losing 2 percent on the batch. Over a season's pack the accumulated loss could be costly to the company.

If water boils at 212° F., jam should be cooked to a finishing point of 222.2° F. if it is to contain 68 percent soluble solids. In other words, when jam in the kettle reaches 222.2° F., as shown on the thermometer, the soluble solids when checked by the refractometer should be 68 percent.

The refractometer reading is made on a small portion of jam containing a representative mixture of fruit and liquid. Place the sample in a test tube, cork it quickly and cool it rapidly in cold water. When the contents are cooled, thoroughly mix any moisture that has condensed on the sides of the tube or cork with the jam and determine the soluble solids by refractometer. If the percentage of soluble solids is too high, add sterile water to reduce it; if too low, continue cooking until the desired level is reached. (If the jam contains a high proportion of large pieces or whole fruit it is particularly important to have a representative sample, or else the refractometer reading may indicate a higher percentage of soluble solids than will actually be present in the final, equalized product.)

Vacuum-kettle Process

Using Fresh Fruit

1. Place the fruit, water and sugar in a steam-jacketed vacuum kettle and heat to 160° F. with agitation. (Before adding sugar to firm fruits, such as cherries, peaches, plums and some berries, simmer the fruit to soften it, as for open-kettle jams.)
2. Apply a vacuum of 28 inches and keep the heat below 140° F. until the soluble solids of the product are at least 80 percent. (Unless the kettle is equipped with a direct reading refractometer the time element has to be worked out experimentally.)
3. Break the vacuum slowly. Add pectin solution with agitation and raise the vacuum to 28 inches. When rapid-set pectin is used with very acid fruits, keep the temperature above 170° F. to avoid presetting. You may have to apply a little heat to get the batch to roll slightly in the pan.
4. Once again break the vacuum slowly. Heat to 170° F. (or a temperature high enough to avoid presetting when acid is added). Add the acid with agitation; check soluble solids and adjust to proper value with sterile water.
5. Heat the batch to 190° F. Agitate it continuously.
6. Draw off jam and fill containers at 185° F. or higher and seal immediately.
7. Cool containers as directed under method for open-kettle jams.

Vacuum jams may be cooled efficiently by use of the vacuum itself. This method is generally used when a low-temperature aseptic fill is used. After heating the jam to 190° F. (step *5*), turn off the steam and apply a vacuum of 28 inches until the temperature drops to the desired level. If compressed air is connected to the vacuum kettle, use it to transfer the cooled jam to the holding tank for filling.

Using Frozen Fruit

For a jam containing a high percentage of whole fruit pieces, drain the juice off the thawed fruit into the kettle, add the sugar and heat to 160° F. with agitation. (If whole fruit pieces are not desired the fruit and the juice can be added to the kettle with the sugar.) Proceed with step *2*. Release the vacuum slowly, add the drained fruit and reheat to 160° F. with constant agitation. To keep the fruit evenly distributed throughout the jam, apply a vacuum of 28 inches, reduce steam pressure on kettle and allow temperature to drop to 140° F.; break the vacuum slowly. This step may be repeated several times during the cooking process. It creates, by mechanical means, a force that impregnates the fruit with sugar and keeps it from floating to the top.

Heat the batch to 170° F., add pectin solution and finish as outlined in steps *3*, *4*, *5*, *6*, and *7*, above.

QUALITY CONTROL

Quality control is essential for the continued production of uniform jam. The tests used are simple and require neither a skilled chemist nor an elaborate laboratory. All you need is a technician with a little training, elementary laboratory equipment, some standard chemicals and reagents and a small room with a sink and several electrical outlets.

Test **every batch of jam** for percentages of total soluble solids and invert sugar (reducing sugar), pH and consistency; record the data with the batch code.

Use your laboratory also for evaluating the ingredients going into the jam. For example, check the soluble solids and acid in representative samples of fruit

to determine the amount of sugar and acid to include in the formula for a batch of jam. Seymour (7) suggests that small-batch test jams be prepared in the control laboratory when you start to use a new supply of fruit, or when you use fruit that has been stored for a long time. He has found that experience gained from these small-scale tests helps reduce waste of time and materials in the plant.

It is beyond the scope of this publication to go into details of analytical methods. The procedures, chemicals and equipment for sugar determinations are fully covered in *Official and Tentative Methods of Analysis* (1) and in the laboratory manual by Ruck (6). A rapid method of sugar analysis (8) developed at the Summerland laboratory is adaptable to jams. If you carry out the procedure as outlined, it gives results as accurate as those obtained by the more complicated and time-consuming official methods.

In addition to routine laboratory equipment for sugar analysis the following will aid considerably in control work:

(1) Refractometers (Figures 2 and 3). Use a direct sugar-reading type with a scale calibrated to read 0.2 percent between 60 and 80 percent soluble solids. Although not essential, a second refractometer covering the sugar range of the fruits to be used is helpful.

(2) pH meter—battery operated or electric.

(3) Spreadmeter (Figure 4). This is a plexiglass plate engraved with a series of concentric circles. The jam sample is released onto the center of the plate

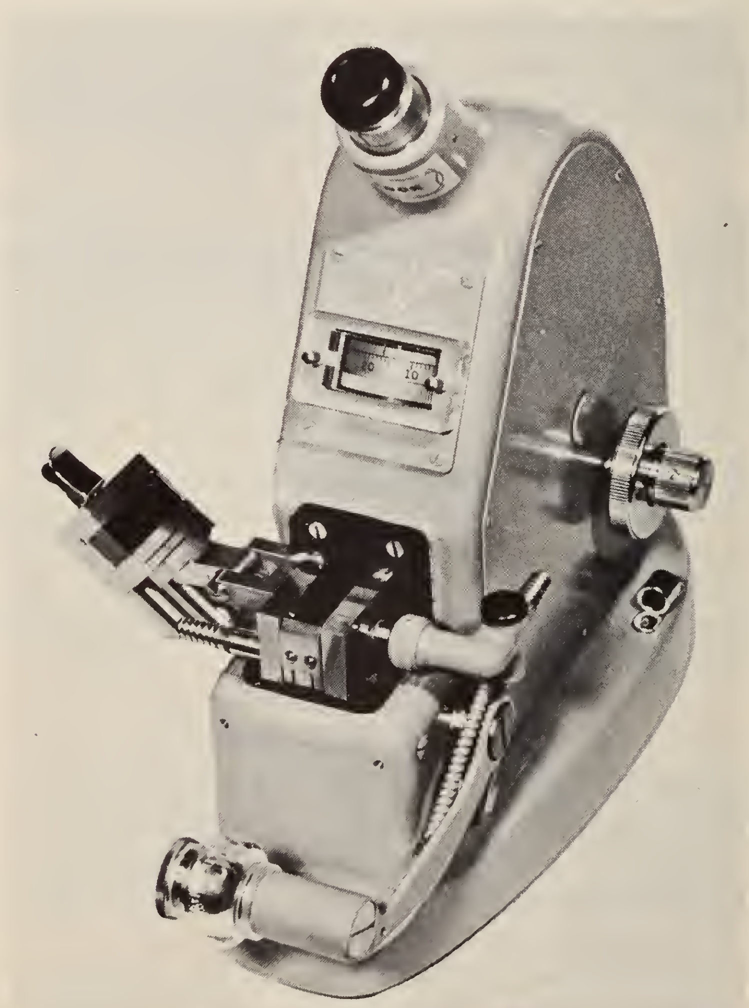

Figure 2.—Sugar refractometer for determining solids, range 0–95 percent.

Figure 3.—Hand refractometer, range 0–80 percent soluble solids.

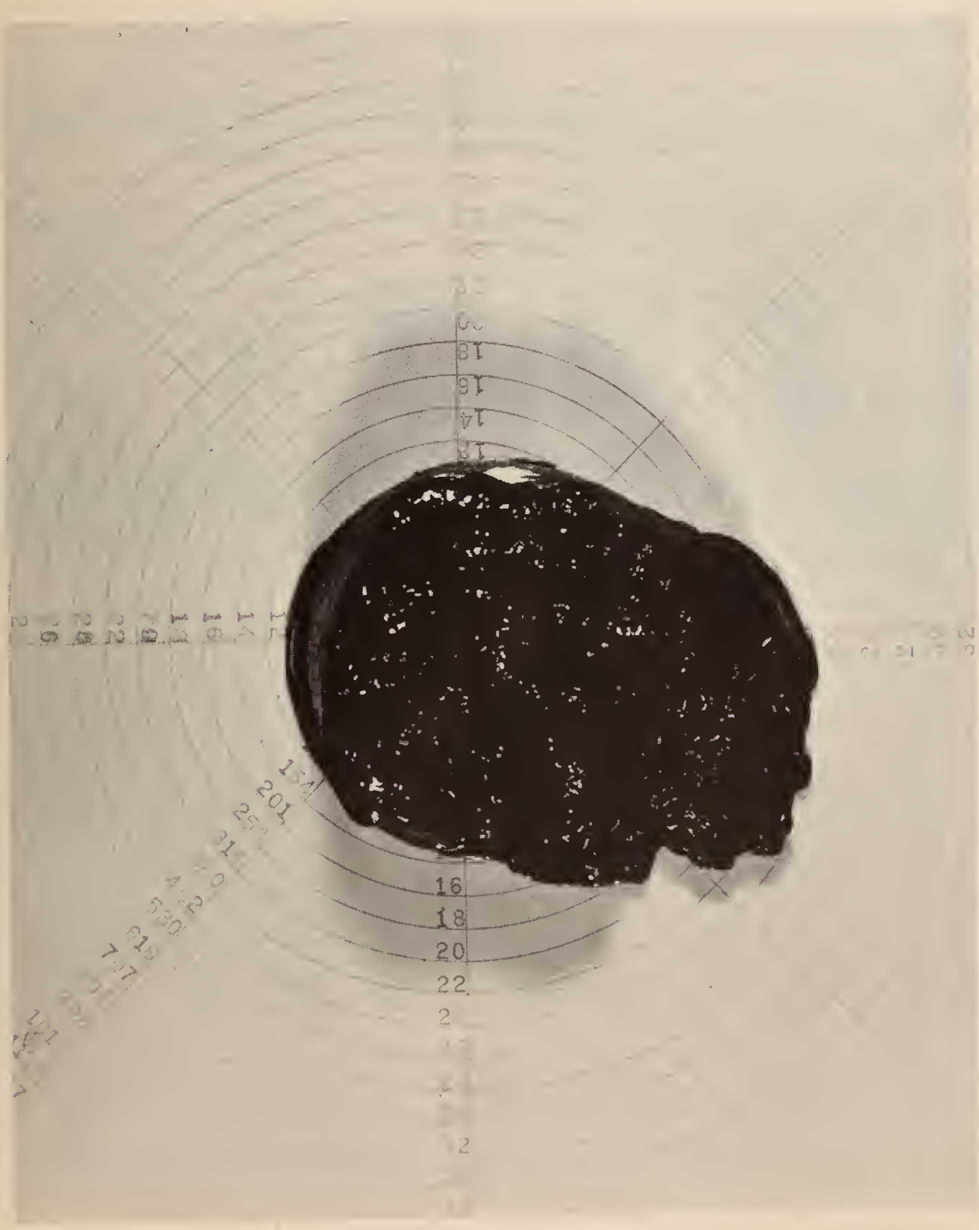

Figure 4.—Spreadmeter for evaluating the consistency or set of a finished jam.

by careful removal of **both** top and bottom of the container. The spread, after 5 minutes, is read at eight points on the plate and the results are averaged. The use of this instrument is limited to tin containers.

PROCESSING EQUIPMENT

Processing equipment for three types of plants is discussed under the following headings:

- The small plant—possibly for specialties.
- The large, manually operated plant—with some mechanical operations.
- The large, mechanized plant—with few manual operations.

The Small Plant

Kettles

Usually a small plant has: (*a*) one or more stainless-steel[5], double-jacketed, steam kettles (Figure 5) operated by a small oil- or gas-fired steam boiler, or (*b*) several small, gas-fired kettles. One plant that concentrates on specialty packs uses *b*, each kettle providing 8 pounds of finished jam per batch.

[5]Stainless steel does not corrode as copper does but it has a slower heating rate. Consequently some English kettles are made of stainless steel except for the heating area, which is copper. Nickel has a faster heating rate than stainless steel but is more expensive.

Figure 5.—Stainless-steel kettles may be obtained in numerous sizes.

Holding Tank

As each batch of jam is finished it is pumped to the holding tank. The tank should have a mechanical agitator and be easy to clean. In one with a jacket (Figure 6), jam can be either heated or cooled. This comes in handy if the filling line breaks down, as unfinished jam can be put into the tank and held at the proper temperature; if left in the kettles the jam might become overcooked.

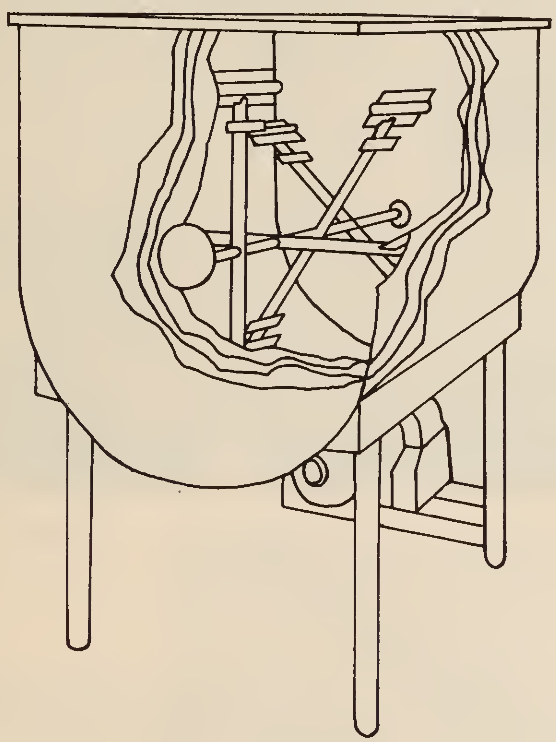

Figure 6.—Holding tank with facilities for heating, cooling or agitating the jam before filling.

Fillers and Cappers

From the holding tank the jam flows by gravity to the filler. A multiple-cylinder filler (Figure 7) is the best kind as it is easily adjusted for different sizes and types of containers. Jars are capped either by hand or by power. A manual capper with steam for vacuum sealing is illustrated in Figure 8.

Capped containers are washed with warm water and left to cool on tables before labeling and casing. It is advisable to space the jars from one half to one inch apart to facilitate cooling.

The Large, Manually Operated Plant

Kettles

This type of plant has several stainless-steel, steam-jacketed kettles but most operations are manual. Dry sugar is weighed and added by hand. Fruit or fruit pulp may be added by hand or pumped in (Figure 9).

The kettles are usually about 24 inches in diameter and 19 inches deep (inside measure), large enough to hold 125 to 150 pounds of finished jam. They

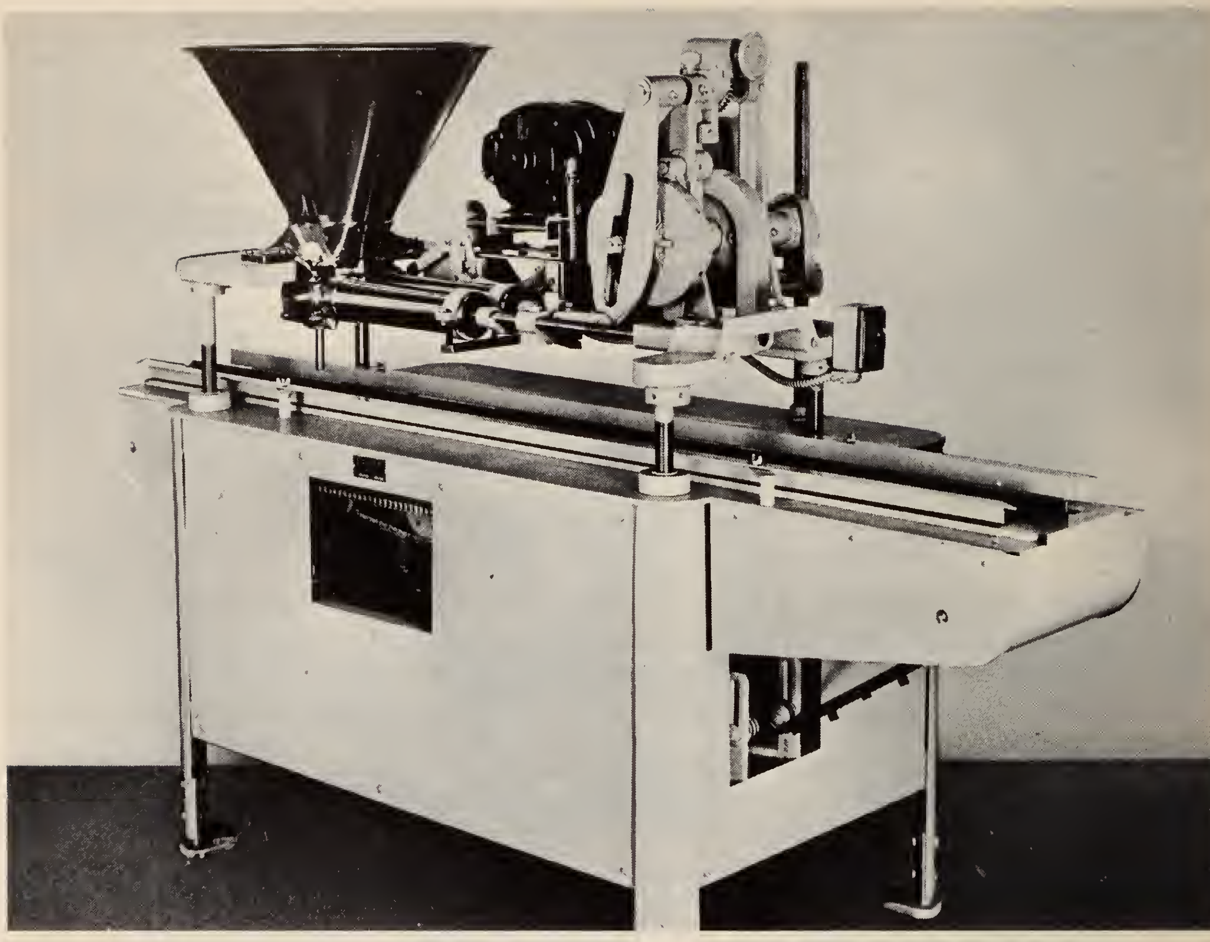

Figure 7.—Filling machine suitable for a large range of container sizes.

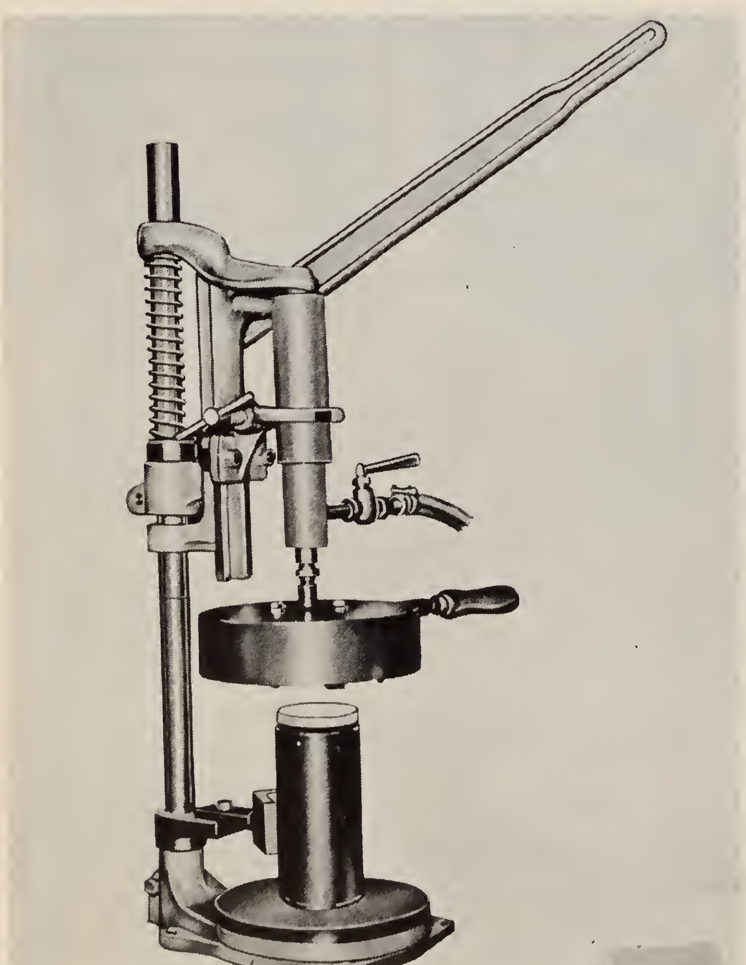

Figure 8.—Manual capper.

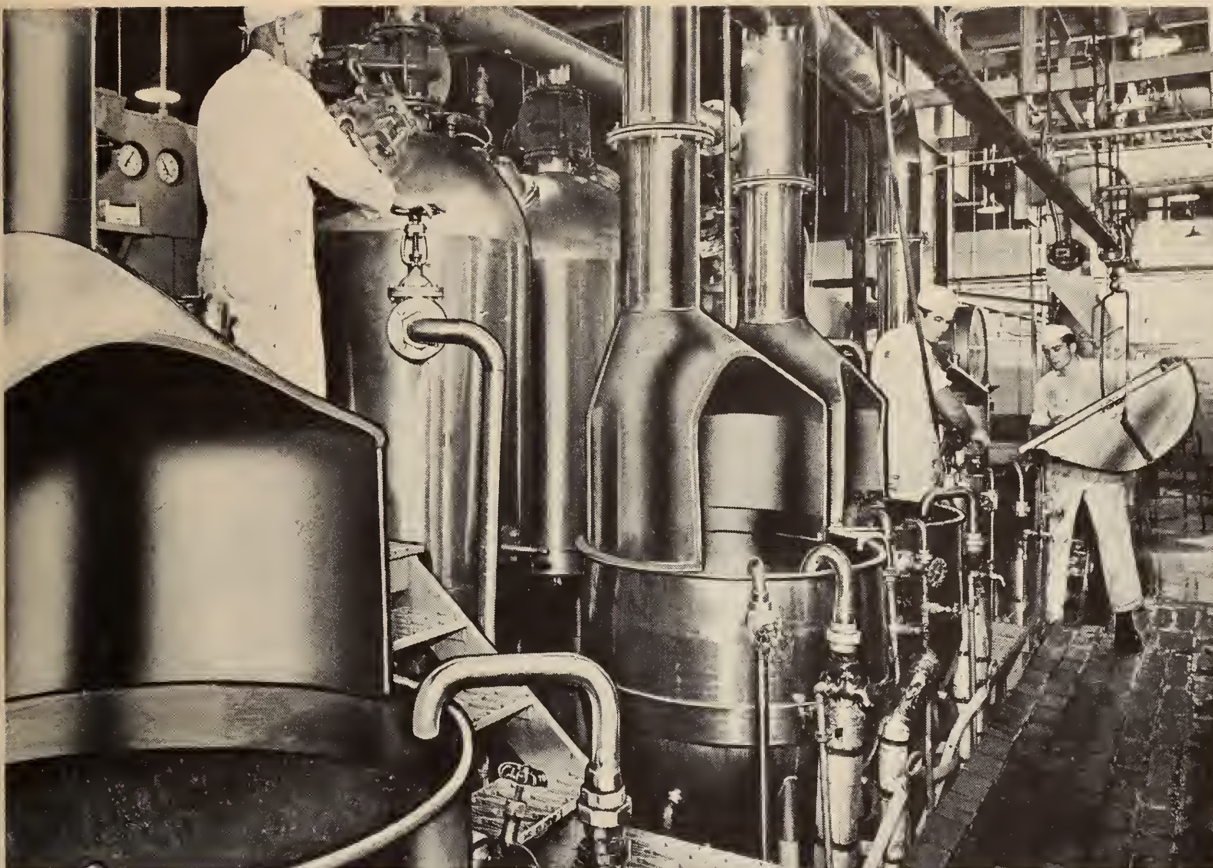

Figure 9.—Several open kettles. Sugar being added by hand.

Figure 10.—Water-jacketed cooling pans.

may be on a balcony, so that the jam flows down to the cooling and filling equipment below, or on the main floor, where the jam is pumped from one piece of equipment to another. A common plan is for the jam to flow from the kettle to a flat cooling pan jacketed with cold water (Figure 10).

Fillers and Cappers

A suitable filler, handling 2- and 4-pound cans besides the various sizes of glass containers, is shown in Figure 11. From the fillers cans go to the closing machines, glass jars to automatic screw-top cappers and tumblers to crimp cappers. For large-capacity lines handling glass, the steam-vacuum, screw-top capper illustrated in Figure 12 is very satisfactory.

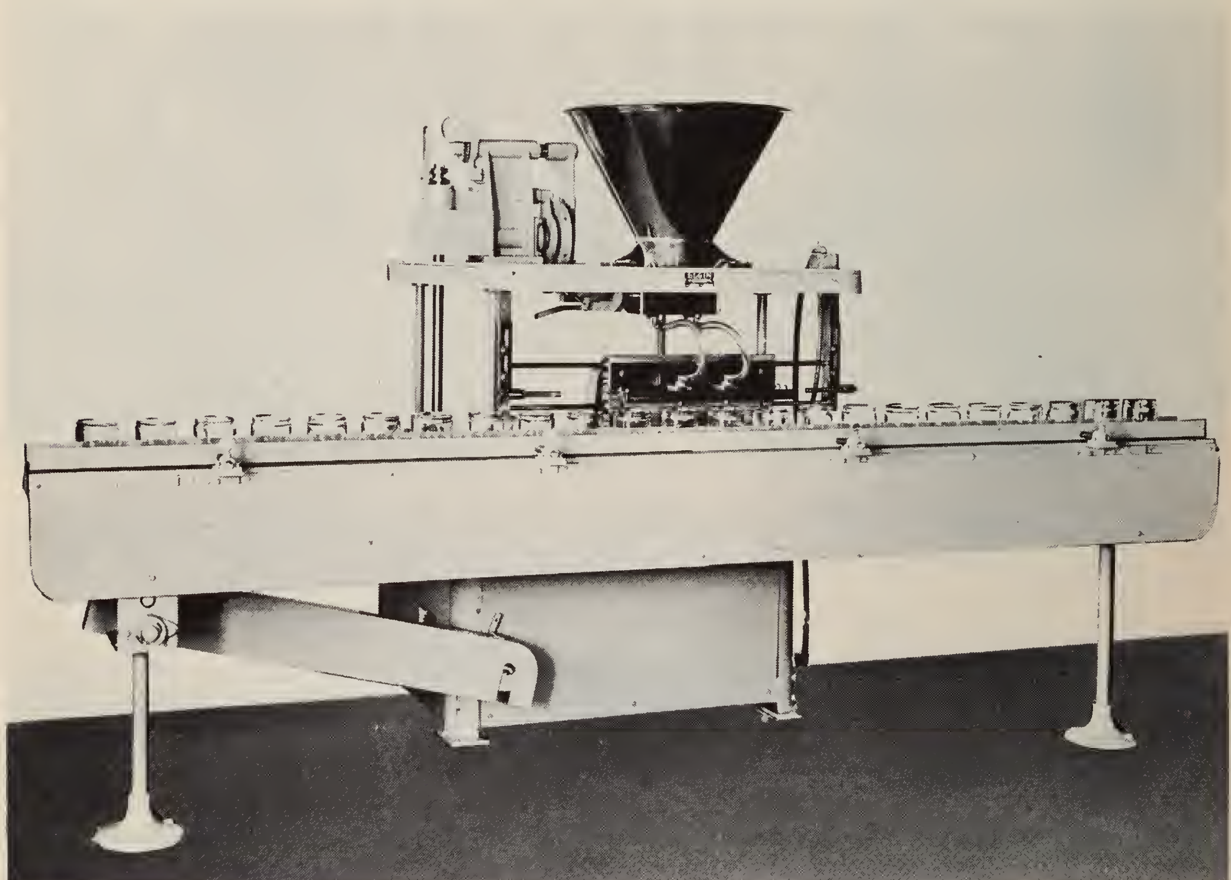

Figure 11.—Large capacity jam filler.

Coolers

After capping, the jam must be cooled to retain quality. Usually in this type of plant a fine water mist is sprayed on the containers as they are conveyed to the labeling machines. Conveyors should not agitate a jam made with rapid-set pectin. Long single-belt coolers, roll-through and walking-beam coolers are all used (Figures 13 and 14).

Labelers

Glass containers, after cooling, dry rapidly and go directly to the spot-labeling machine. Cans, because of their larger size, take longer to dry and may be placed on a table before going to a wrap-around labeler and then to a casing machine.

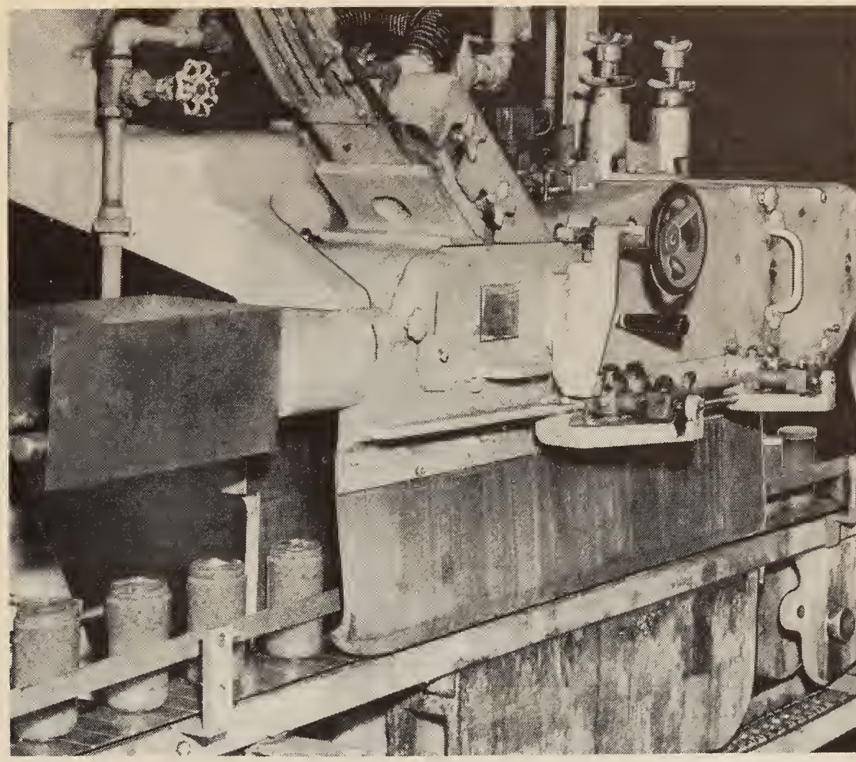

Figure 12.—Steam-vacuum closing machine for screw-top caps for plants of large capacity.

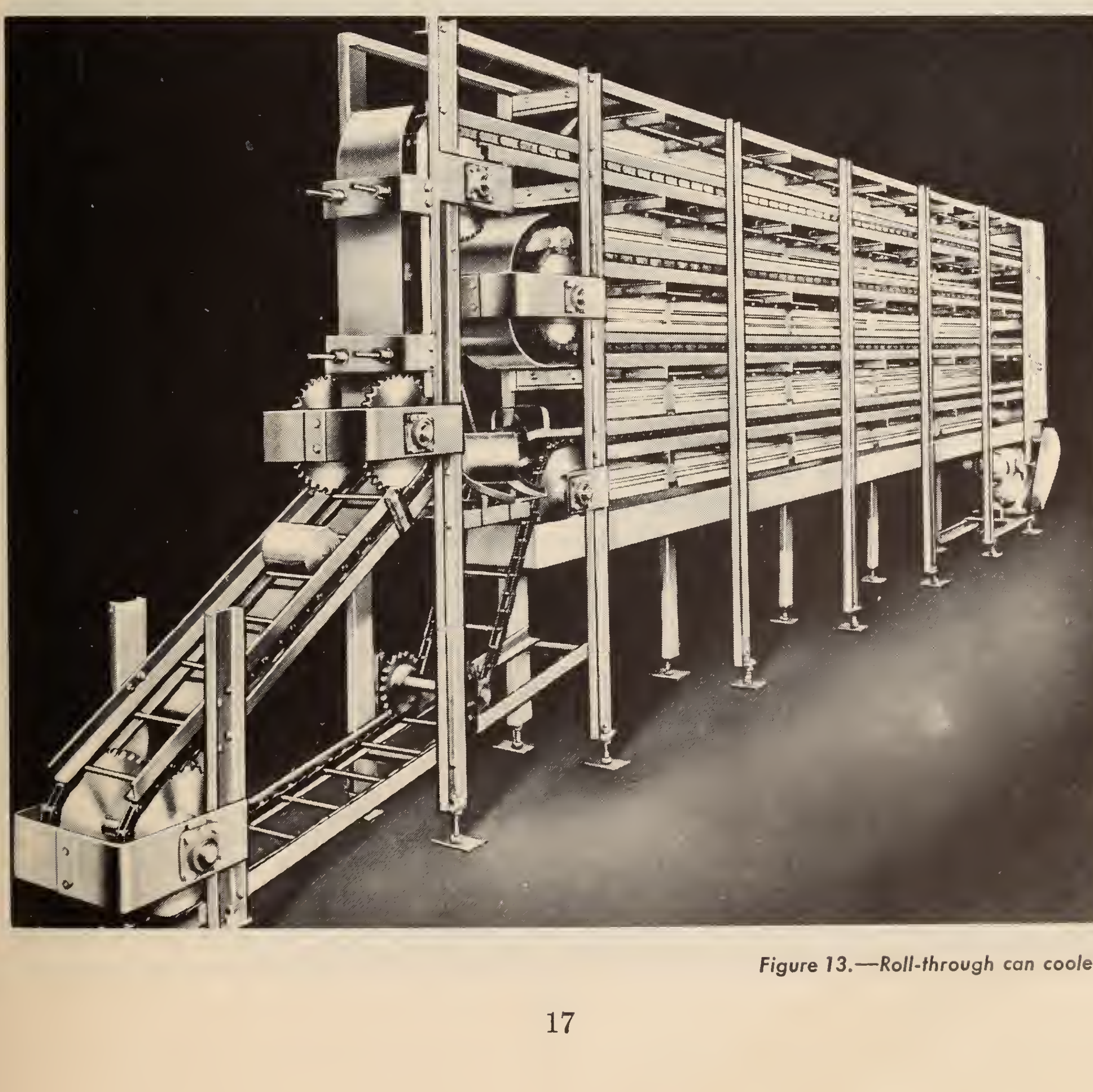

Figure 13.—Roll-through can cooler.

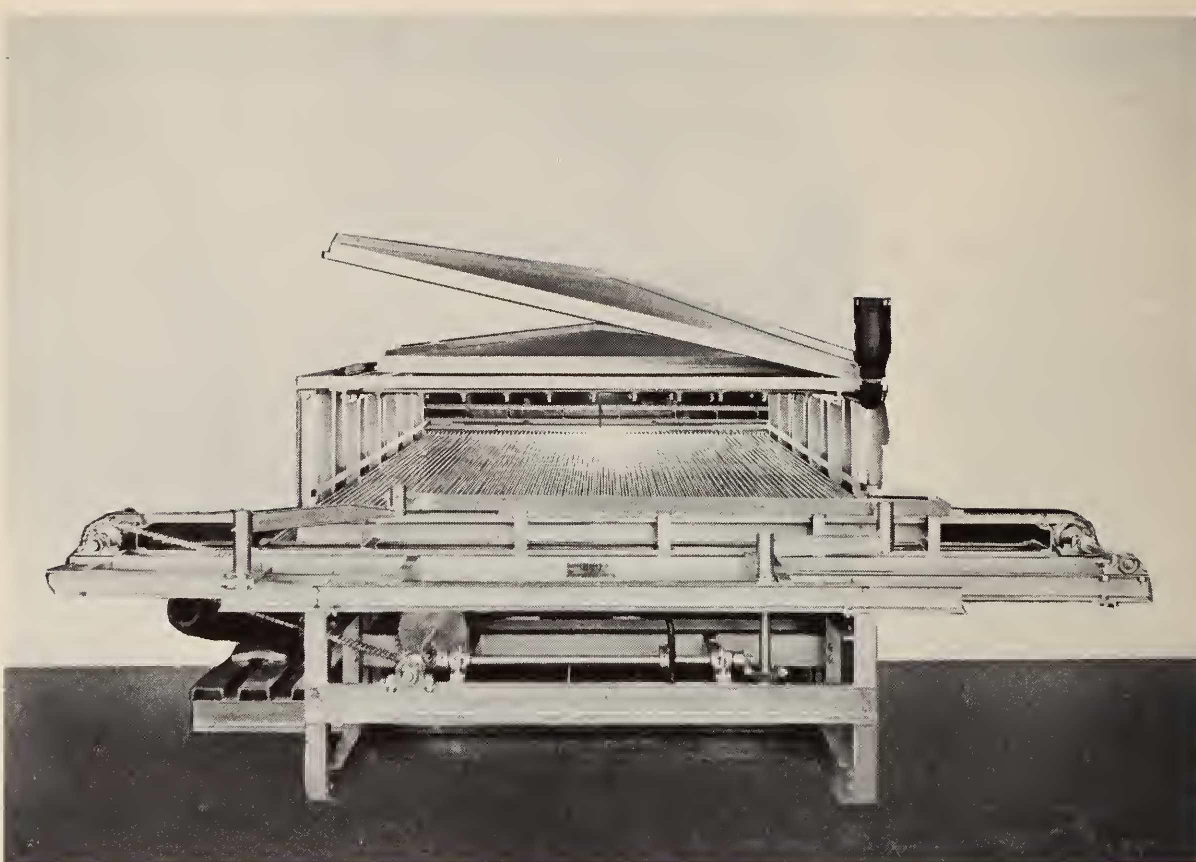

Figure 14.—Walking-beam unit for cooling jam.

The Large, Mechanized Plant

Although the equipment in an automatic jam line may be arranged in several ways, that shown in Figure 15 is typical.

Kettles

If open kettles are used you need at least 12 units, each large enough to hold a 200-pound mix that finishes to 160 pounds. If vacuum kettles are used, larger batches can be made. A satisfactory arrangement would be four kettles holding 500-pound mixes or two kettles holding 2,500-pound mixes.

In both methods the fruit pulp is pumped in and dry sugar[6] or sugar syrup is automatically delivered (or metered) to the kettles. One man adds special ingredients such as pectin and acid to several kettles.

Delivery of fruit pulp.—Fruit pulp is held in a tank serving the battery of kettles and is agitated constantly. The pulp flows by gravity to a positive displacement pump (Figure 16) with a variable speed drive and timing relay; the jam maker merely presses a button to have the right amount of pulp delivered to a kettle. Delivery is through sanitary piping that has one valve and a swinging discharge pipe per pair of kettles.

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[6]Bulk dry sugar is fairly expensive to handle. Before installing any special equipment for it, be sure that the potential savings on the amount of sugar used are large enough to make this a sound investment. Even where dry sugar is the only sugar available in bulk, many operators prefer to make it into a heavy hot syrup to speed up "cooks".

In the Vancouver, B.C., area, sugar-refinery tank trucks deliver bulk dry sugar in 30-ton loads contained in three 10-ton compartments. For unloading, the truck has a special fan and motor that elevates the sugar to storage bins high enough for gravity feed.

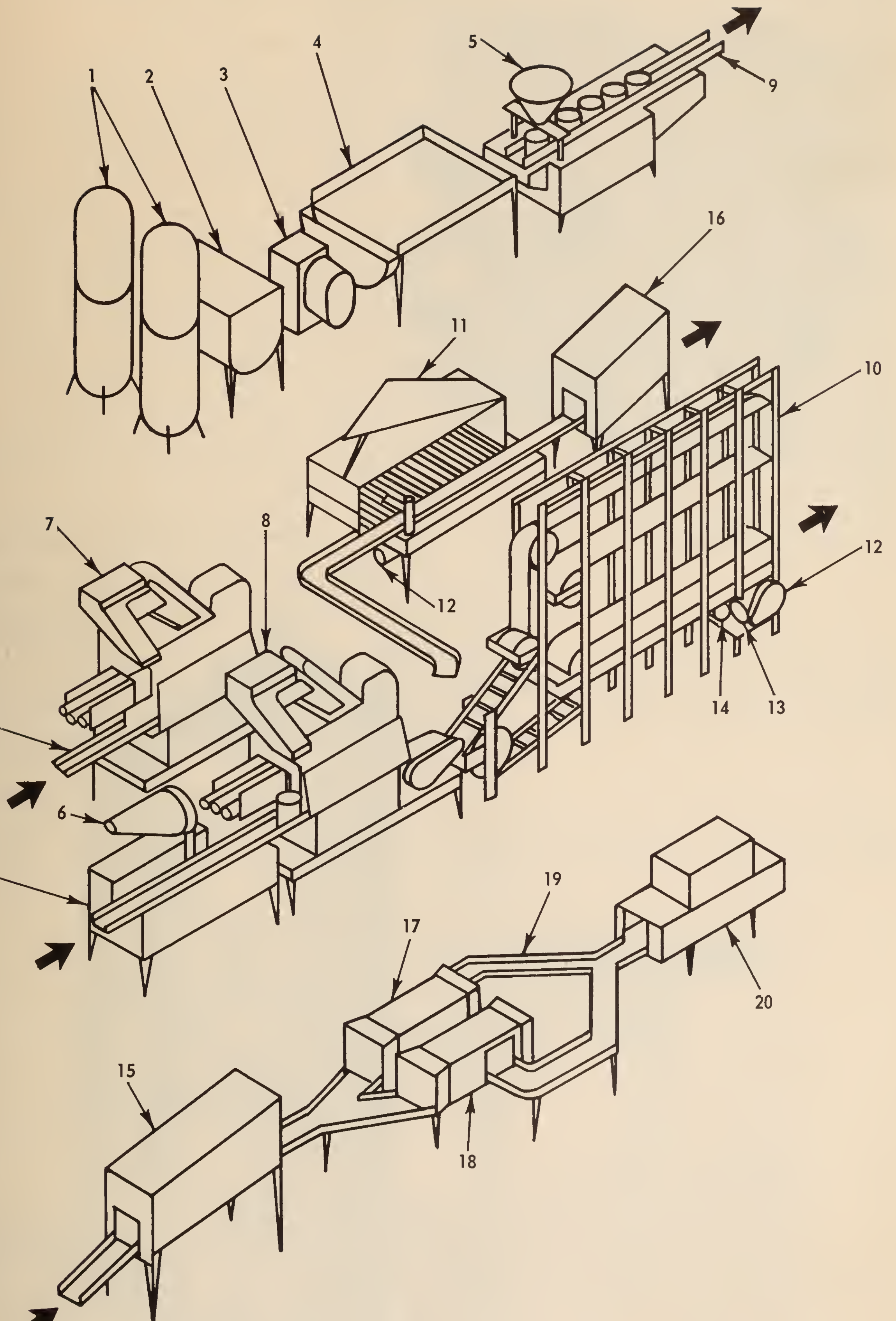

Figure 15.—Equipment for an automatic jam line. 1. Vacuum or open kettle. 2. Holding tank. 3. Jam pump. 4. Inspection table. 5. Filler. 6. Glass capper. 7. Two-pound closing machine. 8 Four-pound closing machine. 9. Flat-top chain conveyor. 10. Roll-through cooler. 11. Walking-beam cooler for glass and tin. 12. Cooler recirculating pumps. 13. Blower. 14. Drier. 15. Roll-through labeler for cans. 16. Spot labeler for glass. 17. 2-pound can casing machine. 18. 4-pound can casing machine. 19. Converging conveyor. 20. Case-sealing machine.

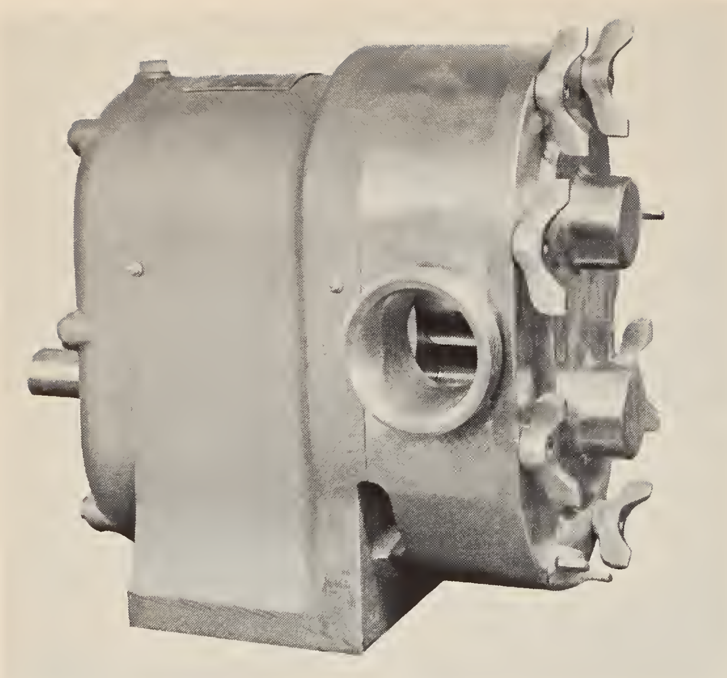

Figure 16.—No. 125 DO Waukesha pump.

Figure 17.—Stainless-steel vacuum kettle.

Vacuum kettles.—Vacuum kettles in the large operation are similar to the one in Figure 17. The jacket is constructed so that either steam or cooling water can be turned into it. A vacuum-breaker valve on the head of the pan is necessary so that ingredients, such as pectin and acid, can be added near the end of the boil. Intake and outlet valves are on the bottom. Through the intake valve, fruit, juice and sugar are sucked by vacuum from the dissolving kettle into the pan. To discharge the jam through the outlet valve, live steam or sterile air under pressure is injected into the pan through the valves above the level of the cooked batch.

Cook end-point controllers.—In the open-kettle method, end-point controllers feed the steam to a double-jacketed kettle through wide-open, three-way valves until the jam reaches the desired temperature. At this point the controller automatically shuts off the steam, opens the third port in the valve and "blows down" or releases any internal pressure on the kettle.

Automatic kettle discharge.—If holding tanks are large enough to handle the jam, equipment for automatic discharge may be installed on kettles. A gate valve, operated by a diaphragm motor, is placed on the discharge of the kettle. As soon as the finishing point is reached, the valve opens to discharge the batch. The jam then flows either by gravity to the holding tank or into a positive displacement pump that delivers it to the tank. At the end of a practical holding cycle for discharging, the gate valve closes automatically.

Holding Tanks

U-shaped holding tanks, like the one in Figure 6, are recommended. This tank has an agitator consisting of paddles that constantly wipe the sides and bottom clean. The heat transfer is good as new jam is continually in contact with the metal of the tank.

Inspection Tables

Before it reaches the filler the jam should be checked for visible foreign material. An illuminated table made from a sheet of fiberglass (Figure 18), with

Figure 18.—Inspection table with illuminated fiberglass bottom for inspecting jam.

the jam flowing over it, simplifies the inspection job and makes it easy to remove undesirable pieces.

Fillers

It is suggested that the jam line in large plants be split at this point, so that one line takes care of 2-pound cans and the other 4-pound cans. A piston-type filler (Figure 11), with a capacity of 80 to 90 pounds per minute, is recommended.

Coolers

Design and number of coolers depend on type of container, space available and temperature desired in the finished product. Enough cooling units should be installed for the temperature of the jam to be lowered to at least 90° F. before casing, to avoid stack burn and darkening of the product.

A roll-through cooler (Figure 13) efficiently lowers the temperature of hot-filled jam in 2- and 4-pound cans to 140° F. This type of cooler should not be used for jam made with rapid-set pectin as it may disturb the set, and give a runny jam. Also, jam packed in glass containers should not be put through a roll-through cooler because breakage is too high. For both of these products a walking-beam cooling unit (Figure 14) is recommended.

Container Driers, Labelers, Casers and Case Sealers

When the containers leave the walking-beam, they must be dry so that labels can be applied. One kind of drier that is very efficient is installed near the exit of the cooling units. The drier provides a large volume of air in two streams—one vertical and the other at an angle. It dries off jars thorcughly but may not remove all water from the lids of cans. However, any water on the lids rolls off when the cans are turned on their sides for labeling. After labeling, the containers are packed in cartons. From the caser the cartons are conveyed to the case sealer and accumulated at the end of the line to form full pallet loads.

FORMULAS

Formula Calculations

To calculate the theoretical output (yield) of a correctly composed formula you should know the soluble solids content of all the ingredients going into the jam. However, in practice you can neglect those contributed by the acid and pectin as they are usually less than 1 percent of the finished weight of the jam.

Sugar Requirements

To determine the amount of sugar required for a batch of jam, you must know the soluble solids content of the fruit. This is best done by taking a refractometer reading on the expressed juice of the fruit itself. However, if you are using frozen fruit containing added sugar, this is not convenient and an average value taken from tables of fruit composition will have to be used.

Suppose you wish to make a 100-pound batch of jam from fresh fruit using the open-kettle method. The jam is to be finished to 68 percent total soluble solids and contain 50 percent fruit. The sugar you need may be calculated as follows:

Example 1

Soluble solids of fruit by refractometer	13 percent
Total soluble solids desired per 100 pounds of jam	68.0 pounds
Soluble solids in 50 pounds of fruit at 13 percent	6.5 pounds
Amount of sugar needed	61.5 pounds

When you cook this mixture of 61.5 pounds of sugar and 50 pounds of fruit to a finishing temperature 10.2° F. above the boiling point of water, the jam will weigh 100 pounds. It will contain 50 percent fruit and have a total soluble solids content of 68 percent.

Acid Requirements

To determine the amount of acid required in a jam, take a 1-pound, representative sample of fruit and run it through a meat grinder, or mix it well in a Waring blendor. Add about 10 percent water, mix thoroughly and titrate with a standard acid solution (citric if it is to be used in the actual process) to the desired pH. This should be about 0.1 pH lower (more acid) than required in the finished jam as it will increase by this amount during the boil.

Prepare a standard citric acid solution by dissolving 2 ounces of citric acid crystals in pure water and making it up to 100 milliliters. Each millileter of this solution contains 0.02 ounces of citric acid.

If a 1-pound sample of your fruit required 8.8 ml. of the standard citric acid solution to lower the pH to 3.1, determine the amount of powdered citric acid required by 50 pounds of fruit as follows:

EXAMPLE 2

1 pound of fruit requires 8.8 ml. of standard solution.
Now, 1 ml. of standard solution contains 0.02 ounces of citric acid.

Therefore, 1 pound of fruit requires $\frac{8.8}{1} \times .02 = 0.176$ ounces of citric acid.

Thus, 50 pounds of fruit require $50 \times .176 = 8.8$ ounces of powdered citric acid.

Pectin Requirements

The best way to determine pectin requirements of a jam is by preparing small test boils in the control laboratory. Suppose that the fruit you are using is fresh Blenheim apricots to be processed by the open-kettle method. You will note, from the apricot jam formula (page 25), that a 200-pound batch of jam made from this variety of fruit by the open-kettle process requires 3 ounces of pectin. Thus, a 100-pound batch would require 1.5 ounces of pectin, and if your test batch is to be finished to 5 pounds try adding ($5/200 \times 3$) or .075 ounces of pectin.

The Test Batch

You are now ready to proceed with the assembling of ingredients and actual cooking of the test batch. Prepare a mix, using the ingredients in the proportions to give a jam of 5 pounds finished weight. Your test formula is as follows:

Ingredient	*Weight per 100-pound batch*	*Weight per 5-pound batch*
Water	5 pounds	.25 pounds
Fruit	50 pounds	2.50 pounds
Sugar	61.5 pounds	3.08 pounds
Acid	8.8 ounces	.44 ounces
Pectin	1.5 ounces	.075 ounces
Finished weight	100 pounds	5 pounds

Carry out the process outlined for open-kettle jam (page 7). About 12 hours after processing, examine the test jam organoleptically and carry out a complete chemical analysis. If the jam is satisfactory, convert the ingredients to amounts necessary for factory-size batches; if unsatisfactory, continue experimentation on a small scale.

Reducing the Fruit Content

If you reduce the fruit content of a jam, first, calculate the sugar and acid required (Examples 1 and 2) on the reduced fruit basis. You will, also, have to use more pectin. For example, if you are using a formula containing 50 percent fruit and reduce the fruit content to 45 percent, try a test batch containing at least 50/45 of the amount of pectin stipulated in the formula.

Using Frozen Fruit

When using sugar-packed frozen fruit, you will have to make allowances for the sugar when composing a formula. For example, if your fruit is frozen apricots (4 + 1), with every 5 pounds of mix you are adding 4 pounds of fruit and 1 pound of sugar. If the soluble solids of the fruit is 13 percent, alter the formula appearing on page 23 as follows:

Ingredients	*Weight per 100-pound batch*
Water	5 pounds
Fruit (4+1)	62.5 pounds (50 pounds of fruit +12.5 pounds of sugar)
Sugar	49 pounds (61.5−12.5)
Acid	8.8 ounces
Pectin	1.5 ounces

Adjusting the Sugar Ratio

Suppose you wish to raise the invert-sugar (reducing-sugar) content of your jam from 15 to 25 percent. To do this the ingoing weight of sucrose sugar must be decreased and that of invert increased 10 percent. As the invert-sugar solution contains 30 percent water, reduce the quantity of water added at the start of the boil by this amount. Your apricot jam formula will now appear as follows:

Ingredients	*Weight per 100-pound batch*
Water 5−(30/100 × 8.8)	2.36 pounds
Fruit	50 pounds
Sugar (sucrose) 61.5−6.15	55.35 pounds
Sugar (70 percent invert) 100/70 × 6.15	8.8 pounds
Acid	8.8 ounces
Pectin	1.5 ounces

Tested Jam Formulas

All jams made from formulas given in this publication (pages 25 to 28) have been thoroughly tested, both chemically and organoleptically, and have stored well for at least 12 months at 70° F. Their fruit content, strawberry 55 percent and all others 50 percent, is higher than the minimum specified in government regulations. For this reason a jam maker, unless putting up a specialty pack, should use these formulas chiefly as a basis for developing formulas of his own.

The formulas are self-explanatory but comments on some of the specific items may be helpful. "Soluble solids of fruit" is the refractometer reading on the expressed juice of a blended representative sample of fruit actually used in the batch. Pectin is 100-grade rapid-set, powdered citrus pectin. It was added as a solution prepared as previously outlined using sugar and water withheld from the batch for this purpose. Acid and sucrose sugar were also added in the dry state. Where invert sugar was used it was added in liquid form as a 70 percent solution and was not neutralized.

Apricot Jam

(50 percent fruit)

Water	18 pounds
Fruit (soluble solids 13.0 percent)	100 pounds
Pectin[7] (100 grade, rapid set)	0–8.5 ounces
Sugar[8]	123 pounds
Acid	7–26 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	22–28 percent
pH	3.30–3.32

Black Currant Jam

(50 percent fruit)

Water	20 pounds
Fruit (soluble solids 11.7 percent)	100 pounds
Pectin[9] (100 grade, rapid set)	0–21 ounces
Sugar[10]	124 pounds
Acid	0
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	22–44 percent
pH	2.93–3.03

Black Currant–Prune Jam

(50 percent fruit)

Water	20 pounds
Black currants (soluble solids 11.7 percent)	50 pounds
Italian prunes (soluble solids 20.4 percent)	50 pounds
Pectin[11] (100 grade, rapid set)	4–10.6 ounces
Sugar[12]	120 pounds
Acid	0
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	20–36 percent
pH	3.2–3.23

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[7]Moorparks required no pectin for open-kettle jams and about 2 ounces per 100 pounds of fruit for vacuum jams. Blenheims required about 3 ounces for open-kettle jams and 6 ounces for vacuum jam.

[8]75 to 100 percent in open-kettle and 70 to 80 percent in vacuum jams should be sucrose, the balance "70" invert.

[9]Use little or no pectin in open-kettle jams and up to 21 ounces in vacuum jams.

[10]No invert sugar required.

[11]Use the smaller amount in open-kettle jams and the larger in vacuum jams.

[12]No invert sugar required.

Sweet Cherry Jam

(50 percent fruit)

Water	20 pounds
Fruit (soluble solids 17.7 percent)	100 pounds
Pectin[13] (100 grade, rapid set)	5.6–8.5 ounces
Sugar[14]	136 pounds
Acid	11–13 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	28.0 percent
pH	3.56

Sweet Cherry–Black Currant Jam

(50 percent fruit)

Water	20 pounds
Sweet cherries (soluble solids 17.7 percent)	76 pounds
Black currants (soluble solids 11.7 percent)	24 pounds
Pectin (100 grade, rapid set)	5.6 ounces
Sugar[15]	120 pounds
Acid	4 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	21–26 percent
pH	3.42–3.58

Sour Cherry Jam

(50 percent fruit)

Water	20 pounds
Fruit (soluble solids 14.5 percent)	100 pounds
Pectin (100 grade, rapid set)	14 ounces
Sugar[16]	122 pounds
Acid	4.2 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	28.0 percent
pH	3.33–3.38

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[13]Use slightly more pectin in vacuum jams to give same set as in open-kettle jams.

[14, 15, 16]Add sucrose only.

Peach Jam

(50 percent fruit)

Water	20 pounds
Fruit (soluble solids 11.2 percent)	100 pounds
Pectin[17] (100 grade, rapid set)	8–12.5 ounces
Sugar[18]	125 pounds
Acid	7.4 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	23–26 percent
pH	3.30–3.35

Italian Prune Plum Jam

(50 percent fruit)

Water	20 pounds
Fruit (soluble solids 20.4 percent)	100 pounds
Pectin[19] (100 grade, rapid set)	7–9 ounces
Sugar[20]	136 pounds
Acid	5.6 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	23–27 percent
pH	3.41–3.45

Raspberry Jam

(50 percent fruit)

Water	16 pounds
Fruit (soluble solids 7.5 percent)	100 pounds
Pectin[21] (100 grade, rapid set)	4.2–8.4 ounces
Sugar[22]	128 pounds
Acid	0
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	20–36 percent
pH	3.22

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[17]Use slightly more pectin in vacuum jams to give same set as in open-kettle jams.

[18]85 percent in open-kettle and 70 percent in vacuum jams should be sucrose, the balance "70" invert.

[19]Use smaller amount in open-kettle jams and the larger in vacuum jams.

[20]86 percent in open-kettle jams and 70–75 percent in vacuum jams should be sucrose, the balance "70" invert.

[21]Satisfactory sets were not obtained on vacuum jams (pH 3.22) with 4.2 ounces of pectin or vacuum jams (pH 3.12) with up to 16.8 ounces.

[22]No invert sugar required. If $CaCO_3$ is added to raise pH of jam to 3.3, probably invert should be added.

Strawberry Jam

(55 percent fruit)

Water	32 pounds
Fruit (soluble solids 7.8 percent)	100 pounds
Pectin[23] (100 grade, rapid set)	3.5–5 ounces
Sugar[24]	116 pounds
Acid	4.2 ounces
Yield (approx.)	200 pounds
Analytical Specifications	
Soluble solids of jam	68.0 percent
Reducing sugar	21–32 percent
pH	3.28–3.32

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[23]Use very slightly more pectin in vacuum jams to give same set as in open-kettle jams.
[24]Add sucrose only.

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